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Aggregate Resources Inventory of
Euphrasia Township
Grey County

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Paper 99

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Abstract

This report includes an inventory and evaluation of sand, gravel and bedrock resources in Euphrasia Township. The report is part of the Aggregate Assessment Office's ongoing inventory of aggregate resources in areas designated under the Aggregate Resources Act.

In Euphrasia Township, 3 areas containing resources of sand and gravel have been selected at the primary level of significance for possible resource protection. Selected Sand and Gravel Resource Areas occupy 800 acres (325 ha), exclusive of licenced properties. An estimated 660 acres (265 ha) are available for extraction, containing resources of approximately 22 million tons (20 million tonnes).

Selected Sand and Gravel Resource Area 1 is a glaciofluvial outwash deposit located in the southwestern part of the township. Resource Area 2, an ice-contact – end moraine deposit, and Resource Area 3, a series of ice-contact – end moraine deposits and an esker, are also located in the southwest. The aggregate in these 3 resource areas is generally of high durability and quality, suitable for a wide range of road-building and general construction products.

Several deposits have also been selected at the secondary level in the township. Although these secondary deposits are not considered the "best" resources, they add considerably to the township's resource base. Care should be taken to ensure the continuing availability of as much of these resources as possible.

Several bedrock formations of Ordovician and Silurian age underlie the township. The Middle Silurian Amabel Formation is the most significant potential source of crushed stone, concrete aggregate, building stone and lime. In areas where the drift cover is less than 25 feet (8 m), the Amabel Formation has been selected for possible resource protection. The Selected Bedrock Resource Areas contain approximately 3700 million tons (3350 million tonnes) of bedrock resources. Some of the resources which lie within the Niagara Escarpment Policy Area may not be available for extraction. These figures represent significant stone resources.

Selected Resource Areas are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

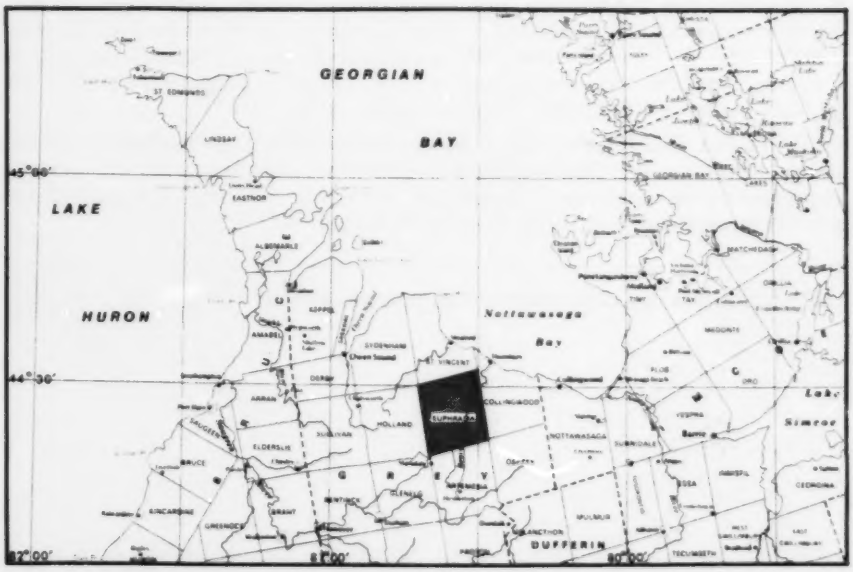

Figure 1. Key map showing the location of Euphrasia Township, Grey County, scale 1:1 800 000.

Résumé

Ce rapport comprend un inventaire et une évaluation des ressources en sable et en gravier ainsi que des ressources du substratum dans le canton d'Euphrasia. Ce rapport fait partie de l'inventaire en cours de réalisation par le Bureau d'évaluation des agrégats sur les ressources en agrégat dans les secteurs régis par la Loi sur les ressources en agrégat.

Dans le canton d'Euphrasia, trois zones contenant des ressources en sable et en gravier ont été sélectionnées comme éventuelles réserves de ressources de première importance. Les zones sélectionnées pour leurs ressources en sable et en gravier couvrent 800 acres (325 ha), à l'exclusion des propriétés enregistrées. Environ 660 acres (265 ha) contenant approximativement 22 millions de tonnes courtes (20 millions de tonnes métriques) sont disponibles pour extraction.

La zone 1 constitue un dépôt d'épandage fluvio-glaciaire situé dans la partie sud-ouest du canton. La zone 2 constituée par un dépôt de contact glaciaire - moraine frontale, et la zone 3 constituée par une série de dépôts de contact glaciaire - moraine frontale et par un esker, sont également situées dans le sud-ouest. Dans ces trois zones, l'agrégat est généralement de grande qualité et durabilité et convient pour de nombreux produits utilisés dans la construction routière et la construction en général.

Plusieurs autres dépôts ont également été sélectionnés dans le canton comme dépôts d'importance secondaire. Bien que ces dépôts secondaires ne soient pas considérés comme des ressources de qualité supérieure, ils ajoutent considérablement à la base de ressources du canton. Un soin particulier devrait être pris afin de faire en sorte que ces ressources restent disponibles autant que possible.

Plusieur formations de l'Ordovicien et du Silurien se trouvent dans le canton. La Formation d'Amabel datant du Silurien supérieur est la source potentielle la plus importante pour la pierre concassée, le granulat pour le béton, la pierre de construction et la chaux. Là où l'épaisseur de la couverture de drift est inférieure à 25 pieds (8 m), la Formation d'Amabel a été choisie comme réserve éventuelle. Les zones sélectionnées pour les ressources de leur substratum contiennent approximativement 3700 millions de tonnes courtes (3350 millions de tonnes métriques) de ressources. Certaines des ressources se situant dans la zone régie par le Niagara Escarpment Policy peuvent ne pas être disponibles à l'exploitation.

Les zones sélectionnées pour leurs ressources ne sont pas destinées à un usage unique et permanent. Elles représentent des zones dans lesquelles une ressource importante a été reconnue et peuvent être réservées entièrement ou partiellement pour l'exploitation et/ou comme réserves de ressources.

Cette publication est disponible en anglais seulement.

Aggregate Resources Inventory of
Euphrasia Township
Grey County

By Staff[1] of the Engineering and Terrain Geology Section

1. Project Supervisor: I. Szoke; field work and report by R. Gorman; compilation by Staff of the Aggregate Assessment Office; drafting by Rod McNeil and Associates. Assistance with review provided by the Resident Geologist, Ministry of Northern Development and Mines, London, Ontario. The Mineral Resources Staff, Owen Sound District, Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 156 million tons (142 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (*see* References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analyzed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Ontario Ministry of Transportation, or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size and depth of extraction of pits licenced under the Aggregate Resources Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The co-operation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000. These base maps are prepared by the Land and Resource Information Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg/m^3).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e., original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel

tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor [the estimated weight in tons of a one-foot (0.3 m) thick section of rock, one acre (0.4 ha) in extent].

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg/m^3) or 3600 tons per acre (8070 t/ha). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg/m^3) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg/m^3).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (*see* Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

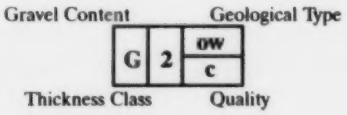
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type) and quality limitations for every deposit shown on Map 1. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30% gravel, 60% sand and 10% silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be

important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 [greater than 20 feet (6 m) thick] and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20% oversize material [greater than 4 inches (10 cm) in diameter] may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and

the test specifications are explained in Appendixes B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C, Hot-Laid Asphaltic Sand Nos. 1,2,3,4 and 8, and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and

described in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Part III—Assessment of Aggregate Resources in Euphrasia Township

LOCATION AND POPULATION

Euphrasia Township occupies 75 507 acres (30 558 ha) in the northeastern part of Grey County, southwestern Ontario. The township is shown on portions of the Markdale (41 A/7), Collingwood (41 A/8), Nottawasaga (41 A/9) and Owen Sound (41 A/10) map sheets of the National Topographic System, at a scale of 1:50 000.

Euphrasia Township has experienced a slight decline in population in recent years. Since 1975, the population of the township has decreased by 7% to a total of 1354 in 1988 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976; Ontario Ministry of Municipal Affairs 1991). Increased farm size and mechanization have contributed greatly to this population decline. The majority of the inhabitants are rural-residential or rural-farm residents. A large number of seasonal visitors support the recreational ski industry in the Beaver Valley. Agriculture is by far the predominant land use and economic activity in the township. Favourable climate, well-drained soil types, proximity to Georgian Bay and a relatively long frost-free season all combine to support many types of agricultural activities. In the Beaver Valley, conditions are ideal for apple orchards.

The communities of Kimberley and Rocklyn, as well as the nearby village of Markdale (Artemesia Township), are the local service centres for the surrounding farm communities. The nearby city of Owen Sound and the towns of Meaford, Thornbury and Collingwood also provide major commercial, industrial and institutional services to the population.

Access within the township is provided by a grid network of paved county and gravel-surfaced township roads.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography, surficial geology and land use patterns of Euphrasia Township are discussed in detail by Chapman and Putnam (1984). In Euphrasia Township, these authors have defined 3 physiographic regions: Beaver Valley, Niagara Escarpment and Horseshoe moraines. A detailed Quaternary mapping and geological study of the area has been undertaken by the Ontario Geological Survey (Feenstra, in prep. a, in prep. b).

The surficial geology of Euphrasia Township is largely the result of glacial activity which took place during the Late Wisconsinan Substage of the Pleistocene Epoch (informally known as the "Great Ice Age"). Approximately 23 000 years ago, lobes or submasses of the Laurentide Ice Sheet advanced out of the Great Lakes basins and covered southern Ontario. These ice lobes underwent numerous fluctuations until the ice finally melted and completely disappeared from the Great Lakes basins. The physiography and distribution of surficial materials in Euphrasia Township, including the sand and gravel deposits shown on Maps 1 and 2 of this report, are the result of the glacial activities and deposits of the Georgian Bay ice lobe during the Late Wisconsinan Substage.

A strong southerly advance of the Georgian Bay ice lobe deposited a coarse gravelly till with a sandy to silty till matrix on the upland portions of the township. In the Beaver Valley, the slopes are covered by till which varies in texture from gravelly sandy silt to silty clay. A part of the Bighead Valley drumlin field occurs in the northern part of the township, northeast of Blantyre. These drumlins consist primarily of gravelly sandy silt till. Till is not acceptable for aggregate use because it contains excessive amounts of fines.

The Beaver Valley physiographic region (Chapman and Putnam 1984) is located in the eastern part of the township, between Kimberley and Heathcote. The Beaver Valley existed prior to glaciation. It was, however, later scoured by the ice sheet during periods of glacial cover. This re-entrant valley, which extends into the Niagara Escarpment, has steep sides of shale and is capped by dolostone. The Niagara Escarpment physiographic region in Euphrasia Township is dominated by the vertical cliffs of the escarpment itself. The face of this bedrock feature trends in a northwest direction across the township.

Much of the area in the southwestern part of the township is included in the Horseshoe moraines physiographic region. As the ice front receded from this region, a variety of sediments were deposited in end moraines, eskers, kames, outwash plains and glacial lake basins. The end moraines deposited in the area include the Singhampton, Gibraltar and Banks moraines (Feenstra 1975; Sharpe 1975). Small morainic ridges and kame complexes also occur between Walters Falls and Fairmount in the Niagara Escarpment physiographic region. The moraines in Euphrasia Township are complex, hummocky features that can consist primarily of either till or ice-contact stratified drift with minor amounts of till. Ice-contact stratified drift is common in parts of all the moraines within the township and especially within the Singhampton Moraine. Ice-contact material has been a traditional source of aggregate in the township.

Between the end moraines there exists a variety of glacial features including eskers, kames, stratified ice-contact deposits and outwash plains. The eskers trend in a southerly direction and were deposited by meltwaters flowing under the ice or in re-entrants in the ice. Two small kames have been identified in the northern part of the township. Kames are generally

hummocky features, deposited by meltwaters in depressions or fissures on the ice surface or at its margin. The eskers, kames and stratified ice-contact deposits contain sand and gravel and several pits have been developed in them. Outwash material, deposited by glacial meltwaters flowing beyond the ice margin, consists largely of well-stratified sand and gravel. A number of outwash deposits located near the Rocky Saugeen River, between the Singhampton and Gibraltar moraines, have been used as aggregate sources.

As the ice margin receded, meltwaters ponded in short-lived proglacial lakes. Glaciolacustrine silts and clays deposited in these lakes are found in the low-lying areas of the township, especially near Wodehouse. These patchy deposits are not well suited for most aggregate uses.

Postglacial erosional and depositional processes have been of minor importance in modifying the physiography of Euphrasia Township. In the northeastern part of the township, the Queenston Formation is being actively eroded by creeks. Gullying here has proceeded so far in places as to produce a badland topography. Alluvial sediments are present along the Beaver River flood plain. Numerous alluvial fan deposits are located at the mouths of gullies that dissect the slopes of the Beaver Valley (Feenstra 1978). The alluvial sediments are not considered acceptable for aggregate use because they generally have a high content of fines. Poor drainage in several upland locations has led to the development of numerous bogs within the township.

EXTRACTIVE ACTIVITY

Fifty-two pits have been identified in this report and their locations are shown on Maps 1 and 2. Many of these pits are currently inactive, overgrown or rehabilitated. The Ontario Ministry of Transportation (MTO) has rated 4 of the pits on their ability to supply road-building and construction materials. Of these pits, 3 received "moderate to high" pit-use ratings and were capable of producing Granular Base Course (GBC) A and Hot-Laid (HL) No. 4 asphaltic stone. The remaining pit received a "moderate" rating and is capable of supplying GBC A (Deike 1982).

At the time of writing there were two pits licenced for extraction under the Aggregate Resources Act. The total area of the two licenced properties in Euphrasia Township is 65.0 acres (26.3 ha). Licenced pit annual production records, on file at the Owen Sound District Office of the Ontario Ministry of Natural Resources, indicate that the average annual production from 1972 to 1986 was approximately 32 000 tons (29 000 tonnes). No quarries have been opened within the township.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 illustrates all of the sand and gravel deposits in Euphrasia Township. Euphrasia Township has 7100 acres (2850 ha) of sand and gravel deposits containing approximately 136 million tons (123 million tonnes) of aggregate. The limited size, thickness and/or poor quality of many of these deposits render them of little practical use. Consequently, only the most significant sources are suggested for possible resource protection.

The sand and gravel deposits selected for possible resource protection in Euphrasia Township are shown on Map 2. One glaciofluvial outwash deposit, 4 ice-contact – end moraine deposits and an esker have been selected as Sand and Gravel Resource Areas of primary significance. These primary resource areas have an estimated 660 acres (265 ha) currently available for extraction and contain granular resources of approximately 22 million tons (20 million tonnes). The primary areas are readily accessible by road.

A number of eskers, ice-contact – end moraine and outwash deposits have also been designated at the secondary level of significance. Although these deposits may possess some quality and workability problems, they serve as important alternative extraction sites. The secondary deposits add considerably to the resource base of the township and should be considered as part of the total aggregate supply.

Aggregate suitability data obtained from MTO indicate that the pits identified within the resource areas generally contain gravel of high durability and quality suitable for use in hot-laid asphalt or concrete mixes (Deike 1982). However, the material may exhibit extreme variability across some deposits. Irregular amounts of fines related to clay-coated sand and gravel, silt and clay seams, and till pockets may be encountered. Zones of cemented gravel have also been observed in some pits. Therefore, it is recommended that specific sites proposed for extractive development should be thoroughly tested, especially if there are plans to use the aggregate for high-specification purposes. Selective extraction and appropriate processing of the material may significantly improve the quality of the aggregate.

Samples, taken from the licenced and unlicenced properties by staff members of the Owen Sound District Office of the Ontario Ministry of Natural Resources, were analyzed for grain size distribution, soundness, absorption and petrography by the Materials Testing Laboratory of the Soils and Aggregates Section of MTO in London, Ontario. The results of these tests are shown in Table 9. The specification limits for each test are included in Appendix E of this report. Granular base petrographic numbers ranged from 100.0 to 116.1, indicating that the gravel quality in the samples was generally good and the aggregate petrographically suitable for use in granular base course and 16 mm crushed stone products. The hot-mix and concrete petrographic numbers ranged from 106.2 to 134.9. These petrographic numbers are generally acceptable in terms of asphalt paving and structural concrete specifications. The percent weight loss, during the Magnesium Sulphate Soundness test for the coarse fraction of the samples, was 0.7 to 2.1, these values are within the ranges for most products. Similar weight loss results were

obtained for the fine fraction of the sampled aggregate with only minor exceptions. When subjected to absorption testing, samples taken from the township had weight gains of 1.17 to 2.62%. Some of these values are higher than the specifications, limiting the uses of the aggregate. Los Angeles Abrasion test data from MTO indicate percent losses which meet the specifications for most products (Deike 1982).

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 is a glaciofluvial outwash deposit located in the southwestern part of the township. Part of pit no. 2 has been opened in the deposit and at the time of field checking, faces in the pit ranged in height from 10 to 25 feet (3 to 8 m). The faces in the southern part of the pit generally revealed well-stratified, fine to coarse, subrounded gravel with coarse sand. A lens of silty fine sand was observed near the top of these faces. The gravel content was estimated to range from 30 to 70% gravel, of which approximately 30 to 50% was crushable gravel.

A sample of the outwash material from pit no. 2 contained 60% gravel, 35% sand and 5% fines (Pit 2a, Figure 3a). This sample contained 36% crushable gravel. Pit-use data compiled from MTO files indicate that, in the past, the aggregate from pit no. 2 has been acceptable for the production of GBC A, B, C and 16 mm Crushed Type A and B. This pit is also capable of producing HL No. 4 and 8 stone. The sand tends to grade coarse and blending would be required for the production of hot-laid sand.

Resource Area 1 occupies 420 acres (170 ha). Cultural constraints reduce the area currently available to 380 acres (154 ha). Assuming an average deposit thickness of 10 feet (3 m), sand and gravel resources are estimated to be 10 million tons (9 million tonnes). The resource area is readily accessible by County roads 12 and 30 which cross the deposit.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is located in the southwestern part of the township between the Singhampton and Gibraltar end moraines. The deposit consists of ice-contact material and exhibits hummocky relief. The northern part of pit no. 2 and two unlicenced pits have been opened in the deposit.

Faces in the pits ranged in height from 10 to 25 feet (3 to 8 m) and contained extremely variable gravel contents. The pit faces exhibited the variability that is characteristic of ice-contact deposits. The material consisted of clean sand and gravel with pockets of till and silty sand. A sample of the material from pit no. 2 revealed 70% gravel, 29% sand and 1% fines (Pit 2b, Figure 3a). The sample contained 39% crushable gravel. Some oversize material was observed in the northern part of pit no. 2. Lenses of cobbly gravel within the pits are potential sources of crushable material if selective extraction measures are employed. Because of the variable nature of this deposit, detailed testing of the material in the undeveloped parts of Resource Area 2 is recommended to delineate areas containing significant quantities of quality aggregate.

Resource Area 2 occupies 85 acres (34 ha), exclusive of licenced properties. Cultural constraints and previous extraction reduce the area currently available to 50 acres (20 ha). Assuming an average deposit thickness of 20 feet (6 m), available resources total 2 million tons (2 million tonnes).

Selected Sand and Gravel Resource Area 3

Four deposits in the southwestern part of the township form Selected Sand and Gravel Resource Area 3. Areas 3a and 3b consist of hummocky ice-contact deposits associated with the Singhampton Moraine, whereas an esker ridge forms Area 3c. Seven unlicenced pits have been developed in these deposits.

Six pits have been developed in Area 3a. Pit no. 46 is located in the western edge of the area. Faces in pit no. 46 exposed up to 25 feet (8 m) of fine to coarse cobbly gravel with fine to coarse sand. The gravel content within Area 3a's pits ranged from 30 to 70%. Samples taken from pit nos. 46 and 49 contained 59 and 69% gravel, respectively (Figure 5a). Varying quantities of clayey silt were observed in some of the pits. The material in the pits appears suitable for a variety of aggregate products with appropriate processing. Because of the variability of material in this type of deposit, selective extraction procedures may be necessary. In sections of the pits, sand control may be necessary for crushing operations, and blending would be required for the production of hot-laid sand.

Similar material may exist in Area 3b. Although no pits have been developed in the deposit, the area is closely associated with the Singhampton Moraine and is similar to Area 3a in terms of its geological origin. Geological data also reveal that gravel is the predominant surficial material at several sites investigated in the deposit. One water well in the deposit also indicates the presence of gravel overlying sand. Detailed subsurface testing of this Resource Area is recommended prior to extractive development.

One pit has been developed in Area 3c. Faces in pit no. 43 reveal 10 to 18 feet (3 to 6 m) of rounded fine to coarse, cobbly gravel with clean coarse sand. The gravel content in the pit was estimated to range from 30 to 60% and the material may be suitable for a variety of aggregate products with appropriate processing.

Resource Area 3 occupies 290 acres (117 ha) in total. Cultural constraints and previous extraction reduce the area currently available to 235 acres (95 ha). Assuming an average deposit thickness of 20 feet (6 m) for Area 3a, and 15 feet (5 m) for Areas 3b and 3c,

available resources total 10 million tons (9 million tonnes). Road access to Resource Area 3 is excellent.

Resource Areas of Secondary Significance

A number of esker, morainic ice-contact and glaciofluvial outwash deposits in Euphrasia Township have been designated as resource areas of secondary significance. These deposits tend to be shallower than those deposits selected at the primary level, however, the secondary selections add significantly to the resource base of the township and should be considered an important part of the total aggregate supply.

Four glaciofluvial outwash deposits have been selected at the secondary level of significance. The deposits contain pit nos. 3, 31, 32, 39, 41, 50 and 51. Faces in these pits ranged in height from 5 to 12 feet (1.5 to 4 m) and generally exposed fine to coarse gravel. This material contained an estimated 30 to 60% gravel. Lenses of clayey silt were observed in pit no. 3 and should be avoided. Pit no. 41 exposed approximately 5 to 6 feet (1.5 to 2 m) of fine to coarse gravel overlying fine to coarse sand. The gravel generally appeared to be suitable for crushing. MTO has tested the aggregate in pit no. 39 and report that the material is generally acceptable for such uses as granular base course, 16 mm crushed stone and HL No. 4 and 8 stone (Deike 1982). Because of the variability of the aggregate, selective extraction procedures may be necessary. The sand grades dirty for hot-laid sand and blending would be required. MTO placed several test holes in the vicinity of pit nos. 50 and 51. Aggregate sampled from the test hole excavations has been rated as acceptable for granular base course, 16 mm Crushed Type B and Select Subgrade Material (Deike 1982).

Three ice-contact deposits, associated with end moraines, have also been selected at the secondary level. The material in these deposits may show a wide variation in grain size. Pit no. 1 and unlicenced pit nos. 20, 21, 26, 27 and 33 are located in the deposits.

Pit no. 1 has been developed in an ice-contact deposit associated with the Singhampton Moraine. Faces in the eastern part of the property generally revealed fine to coarse gravel overlying silty fine to coarse sand. The pit has been rated by MTO as being suitable for the production of GBC A, B and C, 16 mm crushed stone and HL No. 4 and 8 stone (Deike 1982). Pit workability problems include the presence of silt seams which should be avoided during extractive activity. Blending is required for the production of hot-laid sand. A sample of the material from pit no. 1 contained 48% gravel, 47% sand and 5% fines and the gravel generally appeared to be suitable for crushing (Pit 1b, Figure 2a).

The second ice-contact deposit selected at the secondary level is located near Beaverdale. The deposit contains unlicenced pit nos. 20, 21, 26 and 27. Faces in the pits ranged in height from 5 to 15 feet (1.5 to 5 m) and were largely overgrown. The pits generally exposed angular, fine to coarse gravel with occasional clayey silt seams.

Pit no. 33 has been developed in the third ice-contact deposit located south of Beaverdale. The ice-contact material in the deposit is buried beneath an upper unit of till of varying thickness. Faces in pit no. 33 exposed 8 to 10 feet (2 to 3 m) of till overlying 5 to 8 feet (1.5 to 2 m) of fine to coarse cobbly gravel with silty fine sand. Samples of the buried aggregate obtained from pit no. 33 contained more than 50% gravel which appeared to be suitable for crushing (Figure 4a). The buried material may be suitable for a variety of aggregate products with appropriate processing. The illustrated extent of the buried deposit has been based largely on topographic considerations and limited subsurface information. Therefore, further testing may be required to delineate specific sites suitable for extractive development.

The final area selected at the secondary level is an esker deposit located immediately west of pit no. 1. No pits have been developed in this esker, however, 6 to 10 feet (2 to 3 m) of cobbly gravel was exposed in a section of the deposit.

BEDROCK GEOLOGY

Euphrasia Township is underlain by shales of the Upper Ordovician Georgian Bay and Queenston formations as well as by strata of the Lower to Middle Silurian Manitoulin, Cabot Head, Fossil Hill, Amabel and Guelph formations (Map 3) (Liberty 1966; Liberty and Bolton 1971; Burwasser 1974b; Telford 1976; Feenstra, in prep. a, in prep. b). The formations have a gentle regional dip to the southwest. The two dominant geological and geomorphological features in this township are the Niagara Escarpment, a bedrock feature that trends in a serrated fashion northwestward across the township, and the Beaver Valley, a large re-entrant valley in the escarpment.

The Georgian Bay Formation is the oldest bedrock unit in the township and consists of alternating grey carbonate beds and grey to bluish grey shale (Liberty and Bolton 1971). The formation is over 400 feet (122 m) thick in this area and, apart from minor lithologic variation, its chemical composition is fairly consistent throughout its occurrence (Vos 1975). Georgian Bay shale is a raw material which has been used for brick manufacture in southern Ontario, and has also been used for the production of structural drain tile and lightweight expanded aggregate (Guillet and Joyce 1987; Feenstra, in prep. b). In the township, the formation is generally covered by thick overburden, especially on the floor of the Beaver Valley. This formation has not been selected for resource protection because of the thick drift cover.

The Georgian Bay Formation is overlain by the Queenston Formation which underlies the slopes of the Beaver Valley and forms the base of the Niagara Escarpment. This formation consists predominantly of red

shale with occasional beds of mottled green shale and minor grey limestone interbeds (Liberty and Bolton 1971). The formation is exposed in numerous stream valleys, which drain the slopes of the Beaver Valley, and in severely eroded hills in the northeastern part of the township. Although the Queenston shale is a resource of provincial significance in the production of structural clay products, it is relatively carbonate-rich in the southern Georgian Bay area which may limit its potential use (Feenstra, in prep. b). Therefore, the formation has not been selected for possible resource protection.

The Queenston Formation is overlain by the grey and bluish grey, thin- to medium-bedded, fine-grained dolomitic limestone and dolostone of the Manitoulin Formation. Shale partings and lenses of white chert are known to occur within this formation (Vos 1969). The formation generally occurs in a limited area surrounding the Beaver Valley. Stone from the Manitoulin Formation has been extracted from a quarry site in St. Vincent Township, north of Euphrasia Township, for base and subbase road-building aggregate. No areas have been selected for possible resource protection because of the limited exposure of the formation and the availability of better quality bedrock resources in the Amabel Formation dolostone.

The maroon and green, noncalcareous shale and minor calcareous carbonate beds of the Cabot Head Formation overlie the Manitoulin Formation. The thickness of the formation in the area ranges from 37 to 135 feet (11 to 41 m) (Liberty and Bolton 1971). The formation is generally suitable for use as expanded aggregate, brick and tile, but it has not been used for these purposes because exposures suitable for quarrying are scarce (Vos 1969). The Cabot Head shale has not been selected for possible resource protection in Euphrasia Township because of its limited exposure.

The Cabot Head Formation is overlain by the thin-bedded, brown, medium-crystalline, fossiliferous dolostone of the Fossil Hill Formation. The thickness of this formation within the township varies from 6 to 15 feet (2 to 5 m) (Feenstra, in prep. b) and is not well exposed. Since exposures of the Fossil Hill dolostone are very limited along the face of the escarpment, the formation has been grouped together with the overlying Amabel Formation on Map 3.

The erosion-resistant Amabel Formation dolostone forms the cap rock of the Niagara Escarpment and underlies a considerable upland portion of the township, east and west of the Beaver Valley. The Amabel Formation in Euphrasia Township can reach a thickness of approximately 180 feet (55 m) (Feenstra, in prep. b). Within the township, the formation largely consists of fine-crystalline dolostone, although minor amounts of porous, medium- to coarse-crystalline dolostone and patchy occurrences of thin-bedded, dark brown, bituminous dolostone occur (Bolton 1957; Liberty and Bolton 1971). Minor quantities of chert may also be present, especially near the base or top of the formation. Chert is an undesirable material and, if present in an excessively high quantity, may restrict use of the dolostone to low grade aggregate products.

The Amabel Formation is a provincially significant source of aggregate which is suitable for the production of a wide variety of industrial mineral uses including crushed stone, concrete aggregate, building stone and lime manufacture. In the township, those areas of the Amabel Formation that are overlain by less than 25 feet (8 m) of drift have been selected for possible resource protection.

The Amabel Formation often contains an abundance of fossil reef structures which are commonly 50 to 60 feet (15 to 18 m) in height and a few hundred feet in diameter (Hewitt 1960). In Euphrasia Township, numerous reefal mounds and ridges are overlain by 0 to 3 feet (0 to 1 m) of drift and are aligned in easterly oriented belts (Feenstra, in prep. b). The massive beds and irregular surfaces of the reefs may influence the workability of the rock and the porous nature of the reefal dolostone would be expected to increase the absorptive characteristics of the aggregate. The reefal rock is generally softer and less durable than the surrounding rock, and may contain clay pockets and iron staining, particularly near the surface (Hewitt 1960). For these reasons the quality of the reefal rock may be restricted for use as aggregate. However, the nonreefal rock is usually of high quality and is well suited for extraction. Consequently, extractive operations may be better situated within the nonreefal areas.

The youngest bedrock unit in the township, the Guelph Formation, underlies a large area in the western and southwestern part of the report area. The formation is typically a buff to brown, fine- to medium-grained dolostone with both reefal and nonreefal varieties (Liberty and Bolton 1971). The evenly bedded, nonreefal dolostone is better suited for aggregate use than the massive, porous, generally softer, coarser-grained reefal strata. The Guelph Formation dolostone is also a valuable raw material for a range of metallurgical products because of the usually high chemical purity. It is also quarried for the production of dolomitic lime near Guelph and Hamilton. The Guelph Formation has not been selected for possible resource protection because very large resources of more durable Amabel dolostone are available in the township, and local markets for metallurgical products are lacking.

Selected Bedrock Resource Areas 1 and 2

Selected Bedrock Resource Areas 1 and 2 consist of all those areas where the Amabel Formation dolostone is overlain by less than 25 feet (8 m) of glacial sediments. Resource Area 1 is covered by less than 3 feet (1 m) of drift and Resource Area 2 is covered by 3 to 25 feet (1 to 8 m) of drift.

A significant thickness of Amabel Formation dolostone may be available for quarrying as exposures of up to 40 feet (12 m) can be observed along the brow of the Niagara Escarpment, and the formation's thickness

increases in a southwesterly direction away from the escarpment (Vos 1969). The Amabel Formation dolostone is usually of high quality, however, porous reefal structures and chert, where encountered, may restrict some high-specification uses of the aggregate. For these reasons, the quality of the bedrock at a specific site should be investigated prior to extraction.

The Selected Bedrock Resource Areas have a combined area of 20 600 acres (8300 ha), of which 17 200 acres (7000 ha) are presently available for extraction. Assuming an average workable thickness of 60 feet (18 m), available bedrock resources are estimated to be approximately 3700 million tons (3350 million tons). Near the edge of the Niagara Escarpment, considerable portions of the Selected Resource Areas lie within policy areas of the Niagara Escarpment Commission and may not be available for future extractive development. There exist, however, alternative locations within the Selected Bedrock Resource Areas for possible future quarry developments. A large area located between Walters Falls and Epping may provide suitable quarry sites, should there be local or regional demand. The resource areas are readily accessible.

SUMMARY

The sand and gravel deposits of Euphrasia Township are the product of glacial processes which took place during the Late Wisconsinan Substage of the Pleistocene Epoch. In Euphrasia Township, three areas of ice-contact – end moraine, esker and outwash materials have been selected as Sand and Gravel Resource Areas of primary significance. The aggregate in these resource areas is generally of high durability and of quality suitable for a wide range of road-building and general construction products. In addition, several deposits have also been selected at the secondary level in the township.

Euphrasia Township is underlain by Upper Ordovician to Middle Silurian shales and dolostones. The Amabel Formation is considered the most desirable for extractive development. The high quality Amabel dolostone can be used for the production of a wide range of crushed stone and industrial mineral products. Several areas of thinly drift-covered Amabel dolostone have been selected for possible resource protection. The availability of some of the bedrock resources may be restricted because they lie within the policy areas of the Niagara Escarpment Commission.

Enquiries regarding the Aggregate Resources Inventory of Euphrasia Township may be directed to the Aggregate Assessment Office, Engineering and Terrain Geology Section, Ontario Geological Survey, Ministry of Northern Development and Mines, 7th Floor, 77 Grenville Street, Toronto, Ontario, M7A 1W4 [Tel. (416) 965-1663] or to the Resident Geologist, Ministry of Northern Development and Mines, Box 5463, 659 Exeter Road, London, Ontario, N6A 4L6 [Tel. (519) 661-2773] or to the Owen Sound District Office, Ministry of Natural Resources, 611 - 9th Avenue East, Owen Sound, Ontario, N4K 3E4 [Tel. (519) 376-3860].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, EUPHRASIA TOWNSHIP.

1 CLASS NO.	2 DEPOSIT TYPE (*see* Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	G–IC–EM	198 (80)	10 (9)
2	G–E	10 (4)	< 1 (< 1)
	G–IC–EM	385 (155)	14 (13)
	G–K	42 (17)	2 (2)
	S–IC–EM	168 (68)	4 (4)
	S–LP	15 (6)	< 1 (< 1)
	S–OW	300 (121)	10 (9)
3	G–AF	40 (16)	< 1 (< 1)
	G–AL	30 (12)	< 1 (< 1)
	G–E	50 (20)	1 (1)
	G–IC–EM	64 (26)	2 (2)
	G–IC–EM (buried deposit)	60 (24)	1 (1)
	G–OW	800 (325)	18 (16)
	S–IC–EM	1800 (730)	36 (33)
	S–K	5 (2)	< 1 (< 1)
	S–OW	65 (26)	1 (1)
4	G–AF	800 (325)	10 (9)
	G–AL	350 (142)	4 (4)
	G–E	30 (12)	< 1 (< 1)
	G–IC–EM	300 (121)	4 (4)
	G–OW	660 (265)	8 (7)
	S–AF	60 (24)	< 1 (< 1)
	S–AL	190 (77)	2 (2)
	S–IC–EM	120 (49)	2 (2)
	S–OW	560 (227)	7 (6)
TOTAL FOR REPORT AREA:		7100 (2850)	136 (123)

N.B. Minor variations in all tables are caused by rounding of data.

TABLE 2. SAND AND GRAVEL PITS, EUPHRASIA TOWNSHIP.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
Licenced Pits							
1	M4–106	Twp. of Euphrasia	Pt.5	12	10.6 (4.3)	8–12 (2–4)	0–50 variable
2	M4–95	Seeley and Arnill Aggregates Ltd.	Pt.4	11	54.4 (22.0)	10–25 (3–8)	30–70 variable
TOTAL LICENCED AREA:					65.0 (26.3)		
Unlicenced Pits*							
3	–	–	29	11	–	5–12 (1.5–4)	30–50 partially overgrown
4	–	–	29	8	–	5–10 (1.5–3)	variable overgrown
5	–	–	29	8	–	10–20 (3–6)	variable overgrown
6	–	–	29	7	–	5–15 (1.5–5)	variable overgrown
7	–	–	28	4	–	5–8 (1.5–2)	< 20 overgrown
8	–	–	27	3	–	5–10 (1.5–3)	variable overgrown
9	–	–	27	5	–	10 (3)	< 20 partially overgrown
10	–	–	26	8	–	5–10 (1.5–3)	variable
11	–	–	26	12	–	5–10 (1.5–3)	< 10 overgrown
12	–	–	26	12	–	5 (1.5)	< 10 overgrown
13	–	–	26	12	–	5–10 (1.5–3)	< 10 overgrown
14	–	–	22&23	12	–	5–10 (1.5–3)	variable overgrown
15	–	–	23	12	–	5–10 (1.5–3)	variable overgrown
16	–	–	24	7	–	5–10 (1.5–3)	variable partially overgrown
17	–	–	23&24	5	–	5–10 (1.5–3)	< 20 variable partially overgrown
18	–	–	13	11	–	5–10 (1.5–3)	30–40 variable overgrown
19	–	–	14	10	–	5–10 (1.5–3)	30–40 variable overgrown
20	–	–	13	8	–	5–15 (1.5–5)	30–40 variable overgrown

TABLE 2. SAND AND GRAVEL PITS, EUPHRASIA TOWNSHIP.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
21	–	–	13	8	–	5–10 (1.5–3)	variable overgrown
22	M4–121	Dalton	13	4	–	10–20 (3–6)	variable
23	M4–119	Stovold	14	4	–	5–15 (1.5–5)	sand source
24	–	–	11	7	–	< 5 (< 1.5)	< 10
25	–	–	10	8	–	5–10 (1.5–3)	< 10 variable overgrown
26	–	–	12	8	–	5–15 (1.5–5)	30–40 variable overgrown
27	–	–	12	8	–	5–15 (1.5–5)	variable partially overgrown
28	–	–	11	10	–	5–12 (1.5–4)	20–30 variable partially overgrown
29	–	–	11	10	–	5–12 (1.5–4)	20–30 variable partially overgrown
30	–	–	12	12	–	5–10 (1.5–3)	overgrown
31	–	–	9	12	–	5–8 (1.5–2)	40–60 overgrown
32	–	–	8	12	–	5–8 (1.5–2)	30–50 overgrown
33	M4–141	Wiley	9	9	–	5–20 (1.5–6)	40–70
34	–	–	9	6	–	5 (1.5)	overgrown
35	–	–	7	8	–	5–10 (1.5–3)	< 20 overgrown
36	–	–	5	11	–	10–15 (3–5)	< 20 overgrown
37	–	–	5	10	–	10–15 (3–5)	variable overgrown
38	–	–	4	10	–	10–20 (3–6)	30–50 variable overgrown
39	M4–44	Hill	6	10	–	5–12 (1.5–4)	30–60 variable
40	–	–	5	10	–	10–20 (3–6)	30–60 variable
41	–	–	4	9&10	–	6–10 (2–3)	40–60
42	M4–27	Gordon	3	12	–	8–10 (2–3)	variable overgrown
43	–	–	2	12	–	10–18 (3–5)	30–60 variable

TABLE 2. SAND AND GRAVEL PITS, EUPHRASIA TOWNSHIP.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
44	–	–	3	11	–	5–10 (1.5–3)	variable
45	–	–	3	11	–	10–20 (3–6)	variable
46	–	–	2	11	–	20–25 (6–8)	30–70
47	–	–	2	11	–	5 (1.5)	40 variable overgrown
48	–	–	2	11	–	5–8 (1.5–2)	40–70 variable overgrown
49	–	–	1&2	11	–	5–10 (1.5–3)	40–70 variable partially overgrown
50	–	–	3	9	–	5 (1.5)	30–50 overgrown
51	–	–	3	9	–	5–8 (1.5–2)	30–50 variable overgrown
52	–	–	2	8	–	<5 (<1.5)	30–40 variable

* Abandoned pits or wayside pits operating on demand under authority of a permit.

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, EUPHRASIA TOWNSHIP.

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1	420 (170)	40 (16)	0 (0)	380 (154)	10 (3)	10 (9)
2	85 (34)	25 (10)	10 (4)	50 (20)	20 (6)	2 (2)
3a	60 (24)	0 (0)	30 (12)	30 (12)	20 (6)	2 (2)
3b	220 (89)	20 (8)	0 (0)	200 (81)	15 (5)	8 (7)
3c	10 (4)	0 (0)	5 (2)	5 (2)	15 (5)	<1 (<1)
	290 (117)	20 (8)	35 (14)	235 (95)		10 (9)
TOTAL FOR REPORT AREA:	800 (325)	85 (34)	45 (18)	660 (265)		22 (20)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, EUPHRASIA TOWNSHIP.

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Tons (Tonnes)
3–25 (1–8)	Guelph	60 (18)	1310 (530)	285 (260)
25–50 (8–15)	Guelph	60 (18)	9600 (3900)	2070 (1880)
			10 900 (4400)	2360 (2140)
0–3 (0–1)	Amabel & Fossil Hill	60 (18)	2400 (970)	520 (470)
3–25 (1–8)	Amabel & Fossil Hill	60 (18)	18 200 (7400)	3950 (3600)
2_–50 (8–15)	Amabel & Fossil Hill	60 (18)	10 900 (4400)	2350 (2130)
			31 500 (12 700)	6800 (6200)
3–25 (1–8)	Cabot Head	60 (18)	1280 (520)	246 (223)
25–50 (8–15)	Cabot Head	60 (18)	100 (40)	19 (17)
			1380 (560)	265 (240)
0–3 (0–1)	Manitoulin	40 (12)	500 (202)	72 (65)
3–25 (1–8)	Manitoulin	40 (12)	2600 (1050)	375 (340)
25–50 (8–15)	Manitoulin	40 (12)	1000 (405)	144 (131)
			4100 (1660)	590 (540)
0–3 (0–1)	Queenston	60 (18)	480 (194)	92 (83)
3–25 (1–8)	Queenston	60 (18)	800 (325)	154 (140)
25–50 (8–15)	Queenston	60 (18)	4550 (1840)	870 (790)
			5800 (2350)	1120 (1020)
3–25 (1–8)	Georgian Bay	60 (18)	210 (85)	40 (36)
25–50 (8–15)	Georgian Bay	60 (18)	1620 (660)	310 (280)
			1830 (740)	350 (320)
TOTAL FOR REPORT AREA:			56 000 (22 700)	11 500 (10 400)

TABLE 5. QUARRIES, EUPHRASIA TOWNSHIP.

- NONE -

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, EUPHRASIA TOWNSHIP.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)
1	0–3 (0–1)	2400 (970)	350 (142)	0 (0)	2050 (830)	60 (18)	445 (405)
2	3–25 (1–8)	18 200 (7400)	3100 (1250)	0 (0)	15 100 (6100)	60 (18)	3250 (2950)
TOTAL FOR REPORT AREA:		20 600 (8300)	3450 (1400)	0 (0)	17 200 (7000)		3700 (3350)

TABLE 7. SUMMARY OF TEST HOLE DATA, EUPHRASIA TOWNSHIP.

- NONE -

TABLE 8. SUMMARY OF GEOPHYSICS DATA, EUPHRASIA TOWNSHIP.

- NONE -

TABLE 9. RESULTS OF AGGREGATE QUALITY TESTS, EUPHRASIA TOWNSHIP.

	COARSE AGGREGATE					FINE AGGREGATE
	Petrographic Number					
Sample No.	Granular & 16 mm Crushed	Hot Mix & Concrete	Magnesium Sulphate Soundness (% Loss)	Absorption (%)	Los Angeles Abrasion (% Loss)	Magnesium Sulphate Soundness (% Loss)
1b	108.4	118.2	-	-		15.3
2a	102.2	112.4	2.1	1.80		9.7
2b	100.0	110.8	2.1	1.67		14.4
33a	100.0	106.8	1.8	1.17		8.2
33b	100.0	111.6	1.4	1.39		7.6
46	100.0	106.2	0.7	2.04		13.3
49	108.1	112.8	1.9	2.62		10.4
EU-SS-1a	116.1	134.9	1.5	-		16.4

Note: The quality refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits, care should be exercised in extrapolating such information to the rest of the deposit.

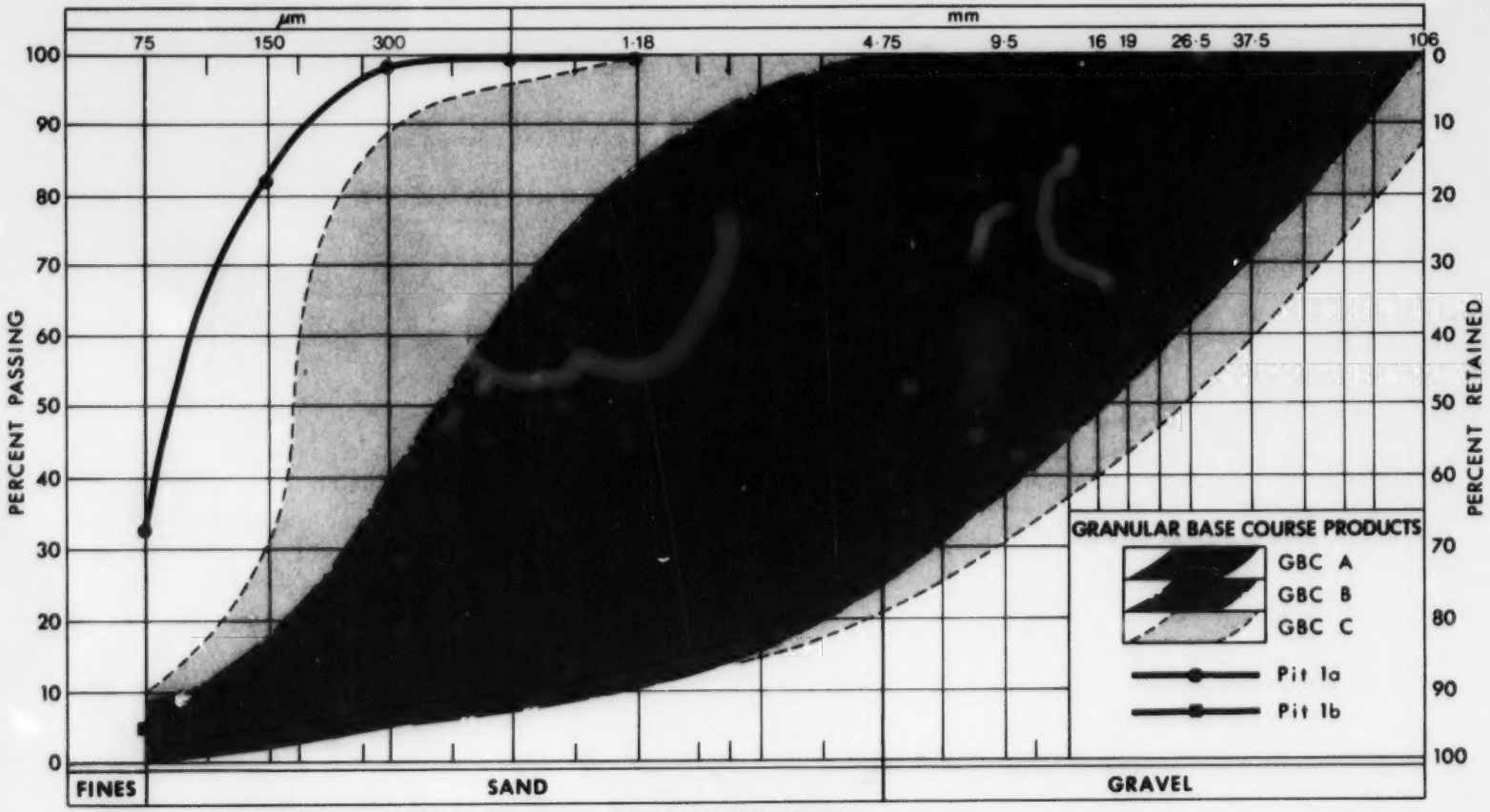


FIGURE 2a. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

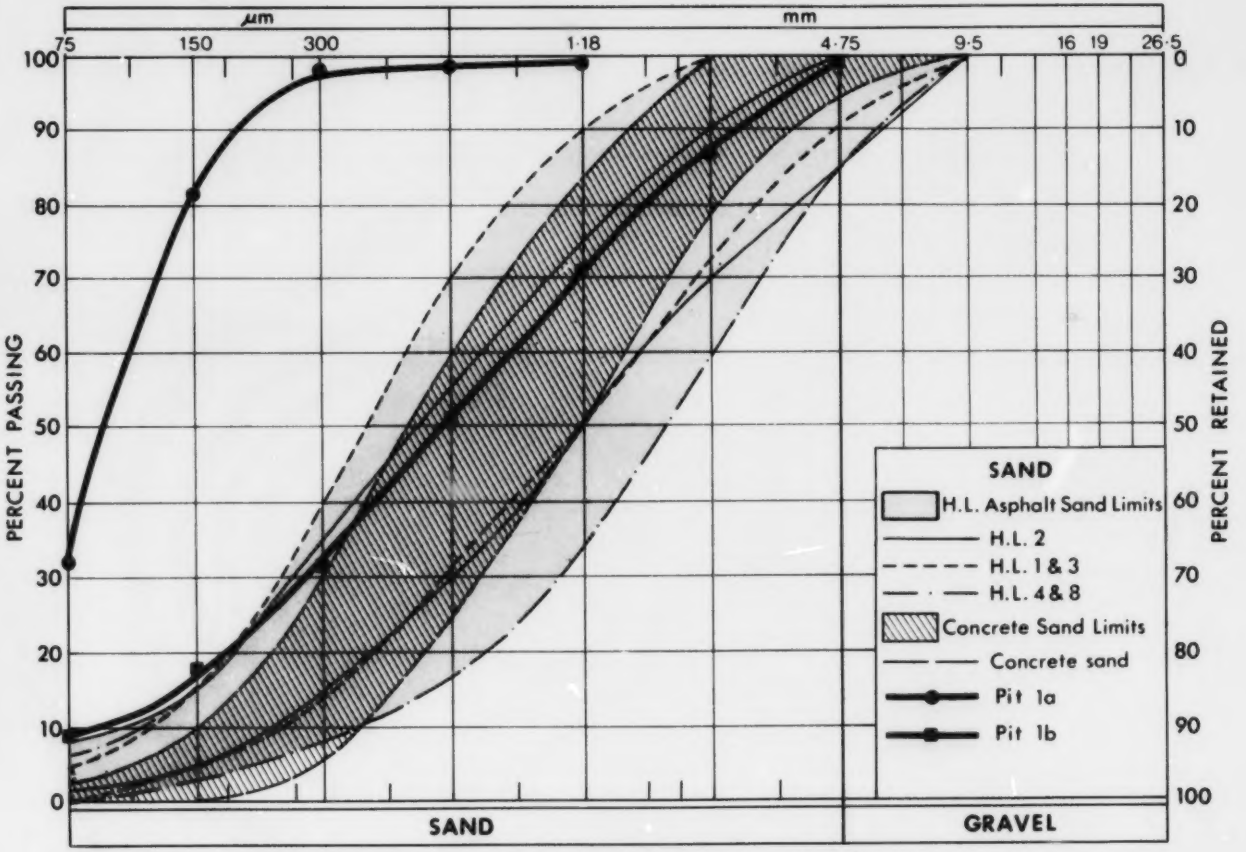


FIGURE 2b. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from MTO Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

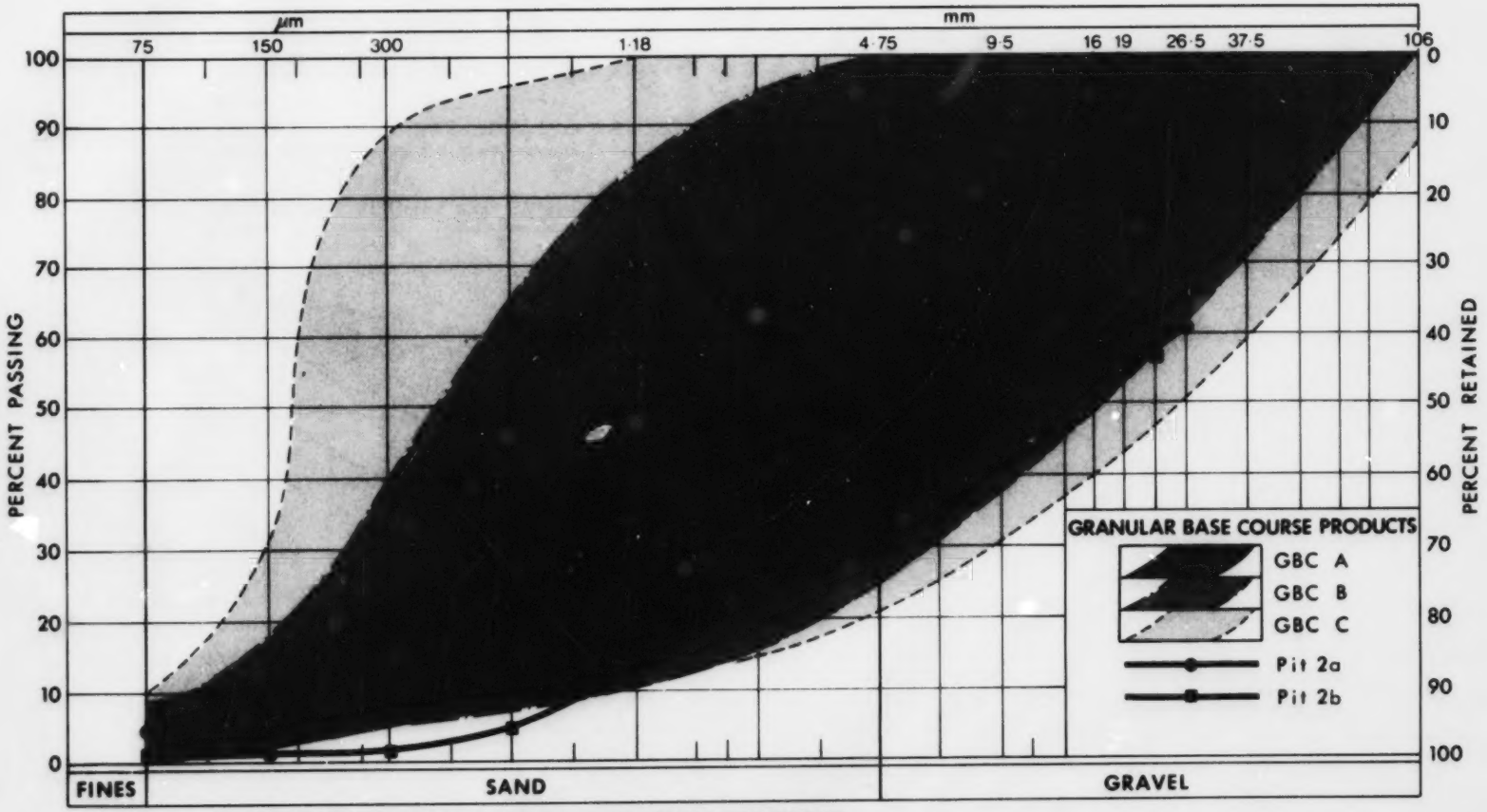


FIGURE 3a. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

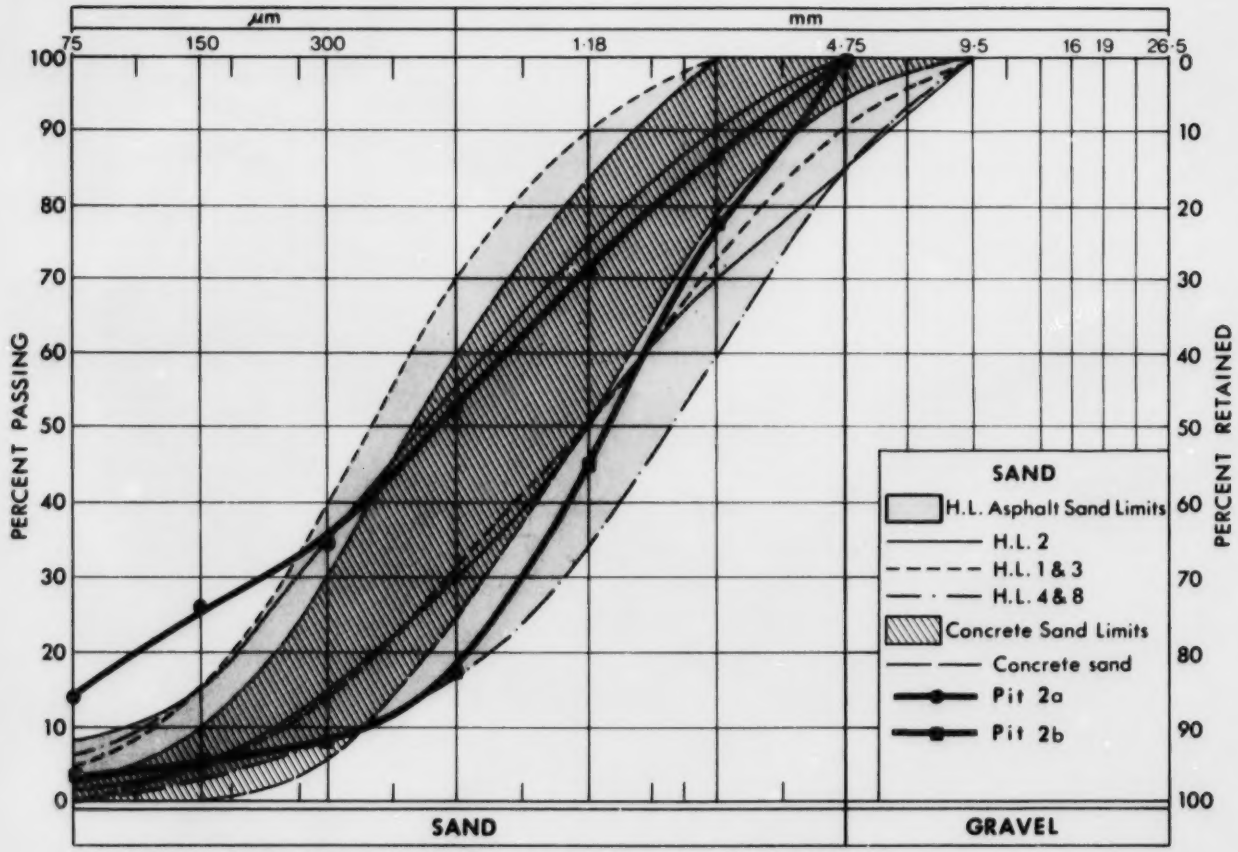


FIGURE 3b. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from MTO Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

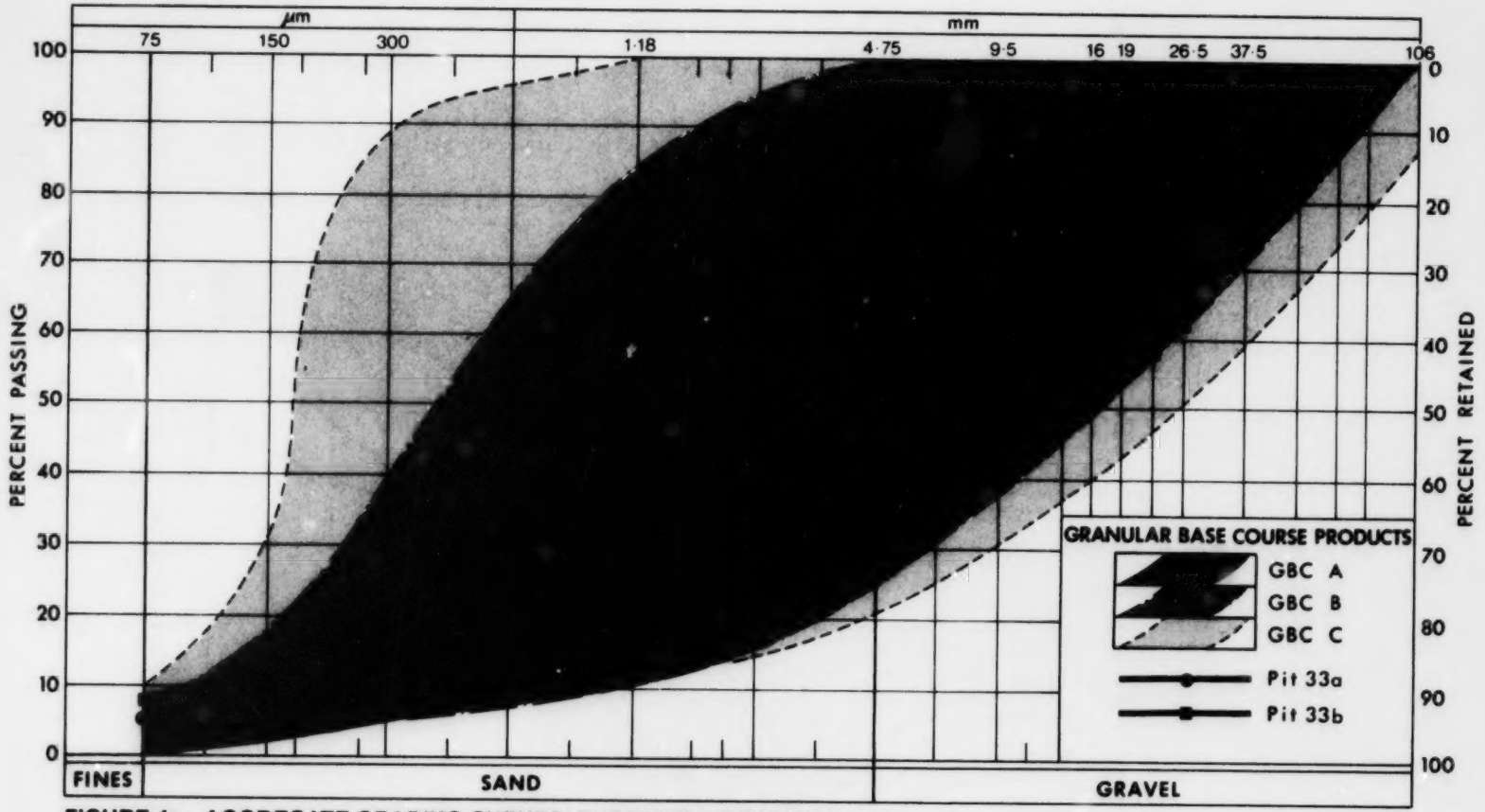


FIGURE 4a. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

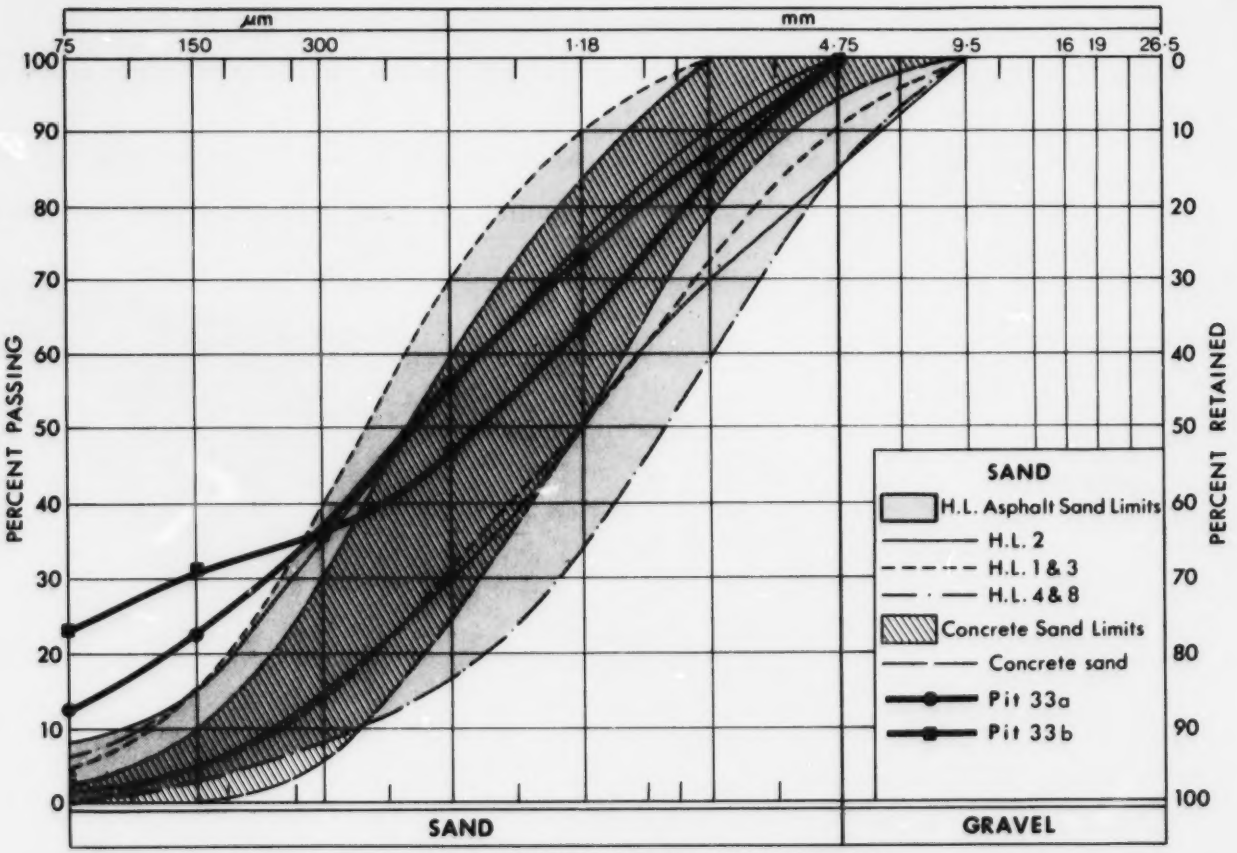


FIGURE 4b. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from MTO Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

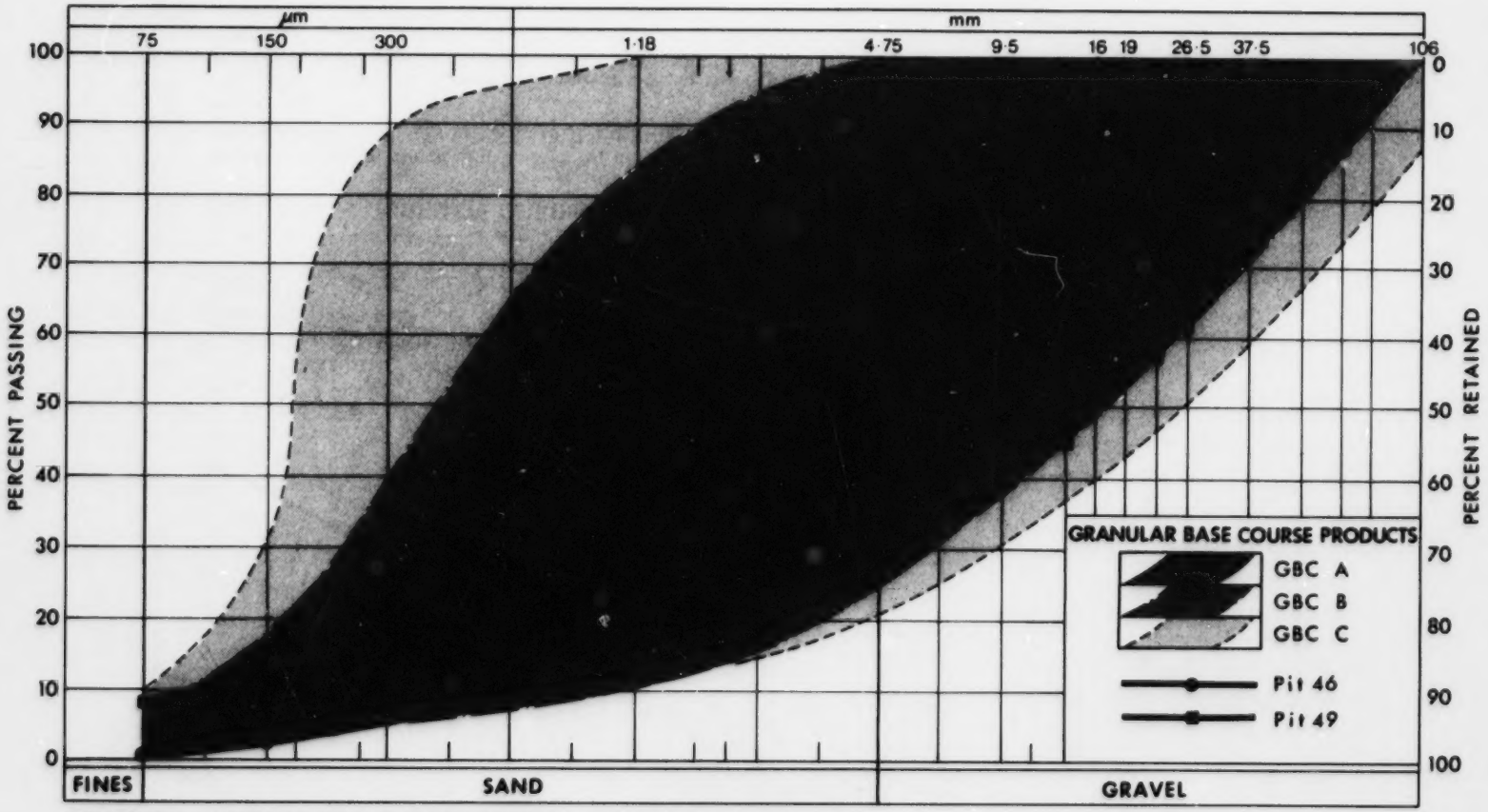


FIGURE 5a. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

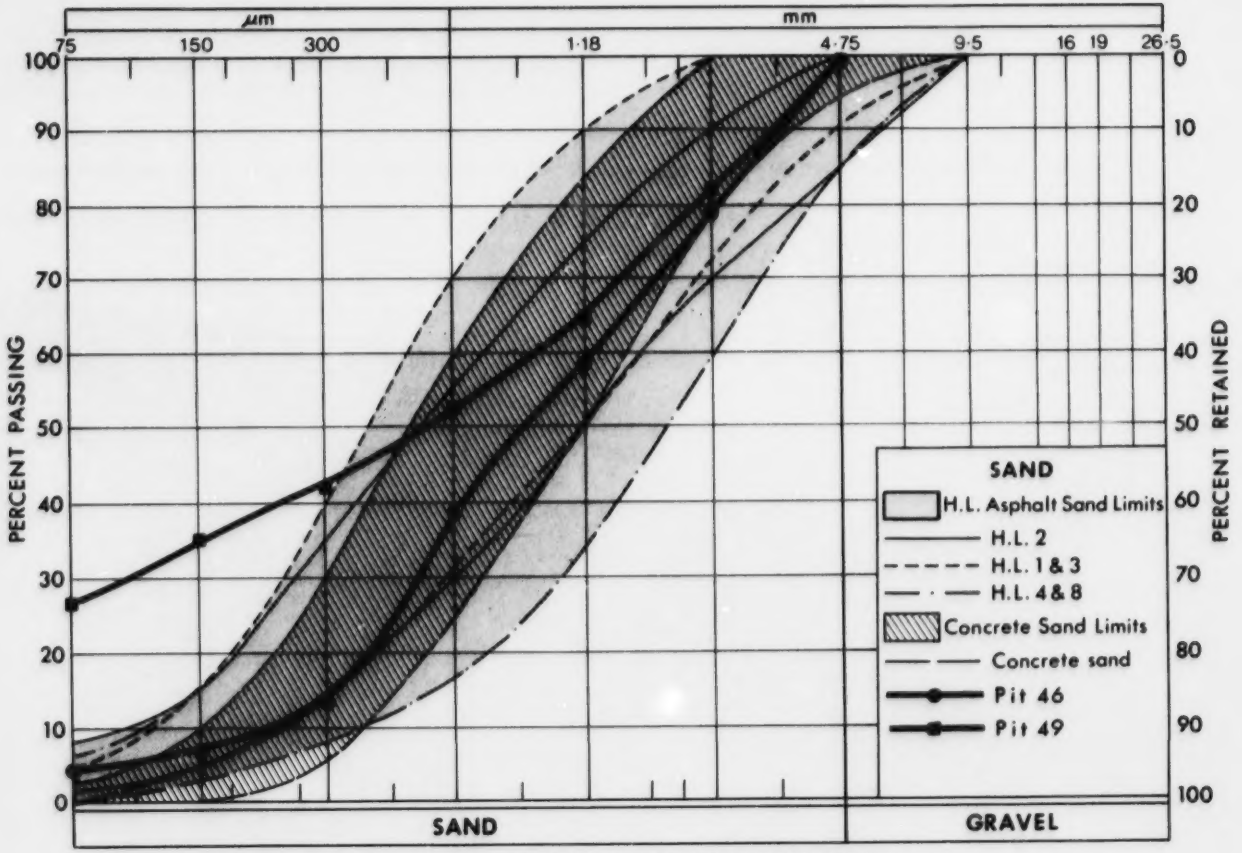


FIGURE 5b. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from MTO Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

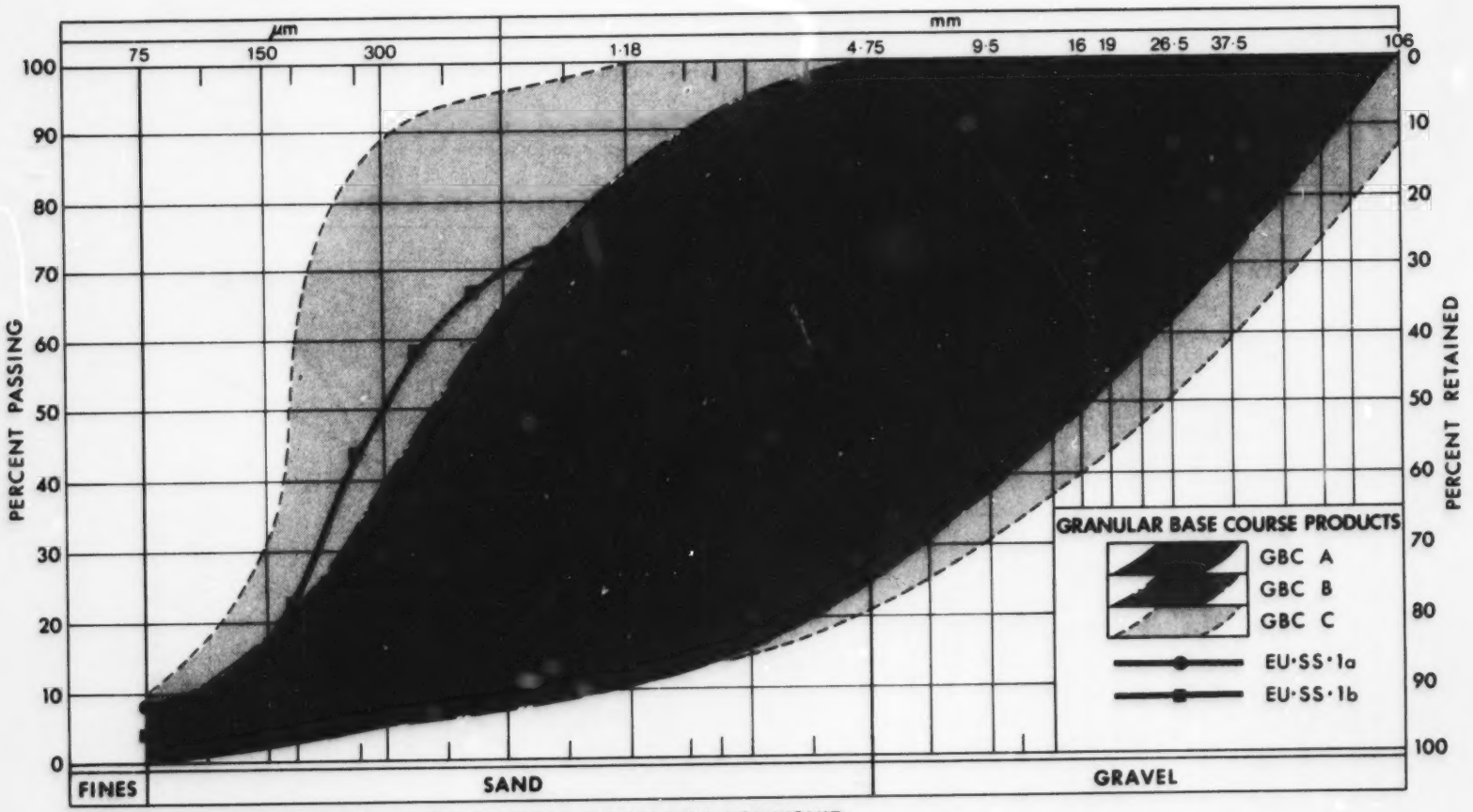


FIGURE 6a. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

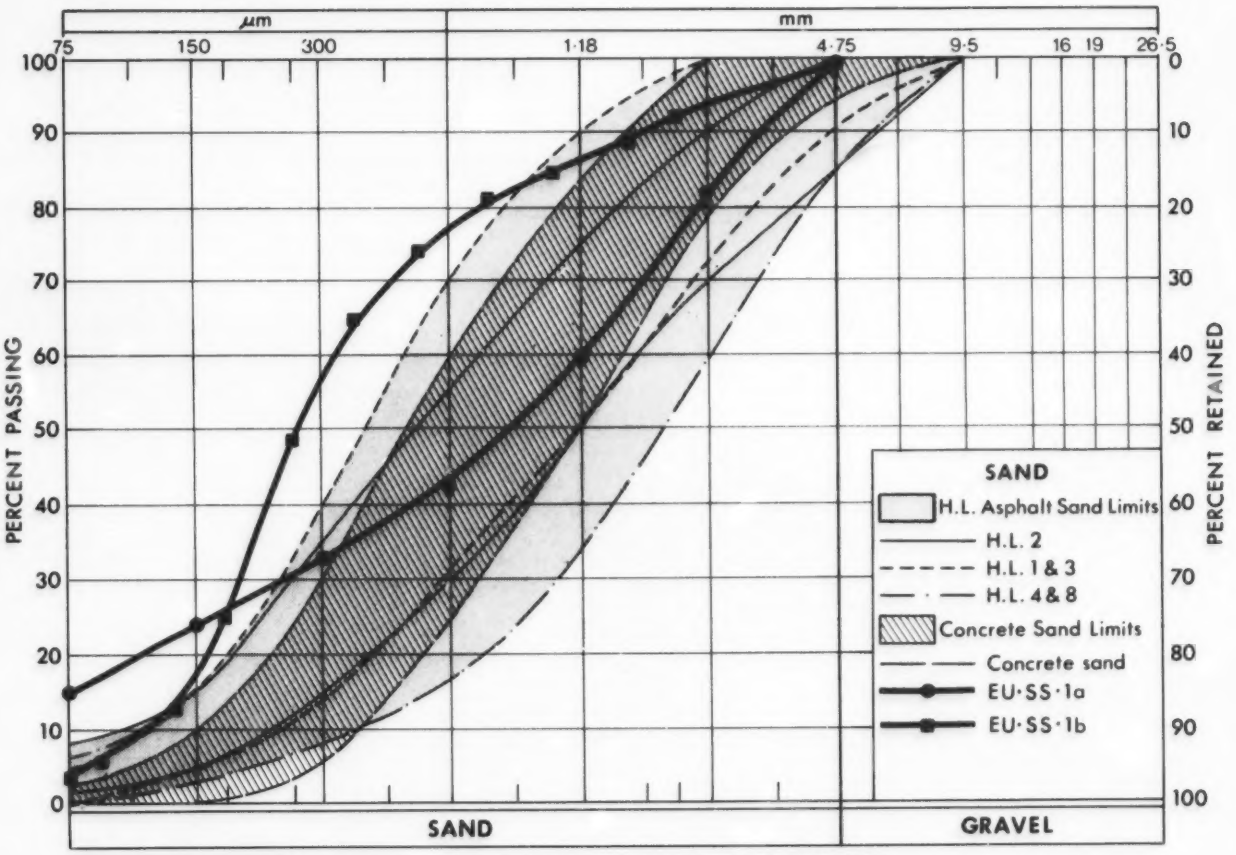


FIGURE 6b. AGGREGATE GRADING CURVES, EUPHRASIA TOWNSHIP.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from MTO Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gr el deposits care should be exercised in extrapolating such information to the rest of the deposit.

References

Association of Professional Engineers of Ontario 1976. Performance standards for professional engineers advising on and reporting on oil, gas and mineral properties; Association of Professional Engineers of Ontario, 11p.

Bolton, T.E. 1957. Silurian stratigraphy and palaeontology of the Niagara Escarpment in Ontario; Geological Survey of Canada, Memoir 289, 145p.

Burwasser, G.J. 1974a. Quaternary geology of the Collingwood-Nottawasaga area, southern Ontario; Ontario Division of Mines, Preliminary Map P.919, scale 1:50 000.

——1974b. Drift thickness of the Collingwood-Nottawasaga area, southern Ontario; Ontario Division of Mines, Preliminary Map P.925, scale 1:50 000.

Chapman, L.J. and Putnam, D.F. 1984. The physiography of southern Ontario, 3rd ed.; Ontario Geological Survey, Special Volume 2, 270p.

Deike, W. 1982. Aggregate suitability evaluation, Township of Euphrasia, Grey County; Aggregate Sources Research, 28p.

Feenstra, B.H. 1975. Quaternary geology of the Markdale area (41 A/7), Grey County; *in* Summary of Field Work, 1975 by the Geological Branch, Ontario Division of Mines, Miscellaneous Paper 63, p.116-118.

——1978. Quaternary geology of the Markdale area (east half), Grey County; *in* Summary of Field Work, 1978 by the Ontario Geological Survey, Ontario Geological Survey, Miscellaneous Paper 82, p.142-143.

——in preparation a. Quaternary geology of the Owen Sound area, Grey County; Ontario Geological Survey.

——in preparation b. Quaternary geology of the Markdale area, Grey County; Ontario Geological Survey.

Hewitt, D.F. 1960. The limestone industries of Ontario; Ontario Department of Mines, Industrial Mineral Circular 5, 177p.

Liberty, B.A. 1966. Geology of the Bruce Peninsula, Ontario; Geological Survey of Canada, Paper 65-41, 8p.

Liberty, B.A. and Bolton, T.E. 1971. Paleozoic geology of the Bruce Peninsula area, Ontario; Geological Survey of Canada, Memoir 360, 163p.

Ontario Interministerial Committee on National Standards and Specifications (Metric Committee) 1975. Metric practice guide; 67p.

Ontario Ministry of Municipal Affairs 1991. Municipal directory 1991; Queen's Printer for Ontario, 226p.

Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976. 1976 municipal directory; Queen's Printer for Ontario, 175p.

Robertson, J.A. 1975. Mineral deposit studies, mineral potential evaluation and regional planning in Ontario; Ontario Division of Mines, Miscellaneous Paper 61, 42p.

Sharpe, D.R. 1975. Quaternary geology of the Durham area (41 A/2), Grey County; *in* Summary of Field Work, 1975, by the Geological Branch, Ontario Division of Mines, Miscellaneous Paper 63, p.113-115.

Telford, P.G. 1976. Paleozoic geology of the Collingwood-Nottawasaga area, southern Ontario; Ontario Division of Mines, Map 2341, scale 1:50 000.

Vos, M.A. 1969. Stone resources of the Niagara Escarpment; Ontario Department of Mines, Industrial Mineral Report 31, 68p.

——1975. Potential clay and shale resources of central Ontario; Ontario Division of Mines, Open File Report 5133, 40p.

Appendix A — Suggested Additional Reading

Banerjee, I. and McDonald, B.C. 1975. Nature of esker sedimentation; *in* Glaciofluvial and Glaciolacustrine Sedimentation, Society of Economic Paleontologists and Mineralogists, Special Paper no. 23, p.132-154.

Bates, R.L. and Jackson, J.A. eds. 1987. Glossary of geology, 3rd ed.; American Geological Institute, Alexandria, 788p.

Bauer, A.M. 1970. A guide to site development and rehabilitation of pits and quarries; Ontario Department of Mines, Industrial Mineral Report 33, 62p.

Cowan, W.R. 1977. Toward the inventory of Ontario's mineral aggregates; Ontario Geological Survey, Miscellaneous Paper 73, 19p.

Fairbridge, R.W. ed. 1968. The encyclopedia of geomorphology; Encyclopedia of Earth Sciences, v.3, Reinhold Book Corp., New York, 1295p.

Flint, R.F. 1971. Glacial and Quaternary geology; John Wiley and Sons Inc., New York, 892p.

Guillet, G.R. and Joyce, I.H. 1987. The clay and shale industries of Ontario; Ontario Ministry of Natural Resources, 157p.

Derry Michener Booth and Wahl and Ontario Geological Survey 1989a. Limestone industries of Ontario, volume I – geology, properties and economics; Ontario Ministry of Natural Resources, Land Management Branch, 158p.

——1989b. Limestone industries of Ontario, volume II – limestone industries and resources of eastern and northern Ontario; Ontario Ministry of Natural Resources, Land Management Branch, 196p.

——1989c. Limestone industries of Ontario, volume III – limestone industries and resources of central and southwestern Ontario; Ontario Ministry of Natural Resources, Land Management Branch, 175p.

Hewitt, D.F. 1964a. Building stones of Ontario, part I introduction; Ontario Department of Mines, Industrial Mineral Report 14, 43p.

——1964b. Building stones of Ontario, part II limestone; Ontario Department of Mines, Industrial Mineral Report 15, 43p.

——1964c. Building stones of Ontario, part III marble; Ontario Department of Mines, Industrial Mineral Report 16, 89p.

——1964d. Building stones of Ontario, part IV sandstone; Ontario Department of Mines, Industrial Mineral Report 17, 57p.

——1972. Paleozoic geology of southern Ontario; Ontario Division of Mines, Geological Report 105, 18p.

Hewitt, D.F. and Karrow, P.F. 1963. Sand and gravel in southern Ontario; Ontario Department of Mines, Industrial Mineral Report 11, 151p.

Hewitt, D.F. and Vos, M.A. 1970. Urbanization and rehabilitation of pits and quarries; Ontario Department of Mines, Industrial Mineral Report 34, 21p.

Lowe, S.B. 1980. Trees and shrubs for the improvement and rehabilitation of pits and quarries in Ontario; Ontario Ministry of Natural Resources, 71p.

McLellan, A.G., Yundt, S.E. and Dorfman, M.L. 1979. Abandoned pits and quarries in Ontario; Ontario Geological Survey, Miscellaneous Paper 79, 36p.

Michalski, M.F.P., Gregory, D.R. and Usher, A.J. 1987. Rehabilitation of pits and quarries for fish and wildlife; Ontario Ministry of Natural Resources, Land Management Branch, 59p.

Ontario Mineral Aggregate Working Party 1977. A policy for mineral aggregate resource management in Ontario; Ontario Ministry of Natural Resources, 232p.

Ontario Ministry of Natural Resources 1975. Vegetation for the rehabilitation of pits and quarries; Forest Management Branch, Division of Forests, 38p.

Peat, Marwick and Partners and M.M. Dillon Limited 1981a. Mineral aggregate transportation study; Industrial Mineral Background Paper 1, 133p.

——1981b. Mineral aggregate transportation study; Industrial Mineral Background Paper 1a, 26p.

Proctor and Redfern Limited 1974. Mineral aggregate study, central Ontario planning region; prepared for the Ontario Ministry of Natural Resources, 200p.

Proctor and Redfern Limited and Gartner Lee Associates Limited 1975. Mineral aggregate study and geological inventory of part of the eastern Ontario region; prepared for the Ontario Ministry of Natural Resources, 326p.

——1977. Mineral aggregate study and geological inventory, southwestern region of Ontario; prepared for the Ontario Ministry of Natural Resources, 246p.

Rogers, C.A. 1985a. Alkali–aggregate reactions, concrete aggregate testing and problem aggregates in Ontario: a review, 5th ed.; Ontario Ministry of Transportation and Communications, Engineering Materials Office, Soils and Aggregates Section, Report EM–31, 44p.

——1985b. Evaluation of the potential for expansion and cracking due to the alkali–carbonate reaction; *in* Cement, Concrete and Aggregates, CCAGDP, v.8, no.1, p.13–23.

Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalies of Portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35% coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20% greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abrasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have

generally low value because of the presence of excess silt- and clay-sized material. There are few large post-glacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate; suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomer-

ates, sandstones, and shales. THICKNESS: eastern Ontario - 7 to 10 feet (2 to 3 m); central Ontario - 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone, whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: quarried in the Lake Simcoe, Kingston, Ottawa, and Cornwall areas for crushed stone; rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: quarried at Brechin, Marysville, and in the Ottawa area for crushed stone; generally suitable for use as granular base course aggregate; rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: quarried at Picton and Bath for use in cement manufacture; quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area; may be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: in eastern Ontario the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; in central Ontario Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: in eastern Ontario the lower member is used extensively for aggregate production; in central Ontario it is quarried at Picton, Ogden Point and Bowmanville for cement; may be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario - Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario - Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: the Blue Mountain Formation is blue-grey, noncalcareous shale; Billings Formation is dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 140 to 200 feet (43 to 61 m); Billings Formation - 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: in central Ontario the Georgian Bay Formation is composed of interbedded limestone and shale; in eastern Ontario the Carlsbad Formation is composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation is 300 to 560 feet (91 to 170 m); Carlsbad Formation - 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation is

used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate; Carlsbad Formation is used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: there are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa; all extract shale for brick manufacturing; the Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Penninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 - 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: no data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile; lack of suitable exposures has limited its use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 - 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part, to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment, as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation is fine- to coarse-crystalline dolostone with high silica content; Reynales Formation is thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 20 to 85 feet (6 to 26 m); Reynales Formation - 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15 to 60 feet (5 to 18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa members. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: some areas appear soft and unsuitable for use in the production of load-bearing aggregate; this unit requires additional testing to fully establish its aggregate suitability; main use is for dolomitic lime for cement manufacture; quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: gypsum mines at Hagersville, Caledonia, and Drumbo; salt is mined at Goderich and Windsor, and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability; has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: has been quarried for silica sand, building stone, and armour stone; may be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSITION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: quarried at Hagersville, Cayuga, and Port Colborne for crushed stone; material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m) USES: quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne; high chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete; has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Penninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone and dolostone with grey chert nodules; Formosa Reef Limestone is high purity (calcium rich) limestone; Sylvania Sandstone Member is quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminous laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: most important source of high-purity limestone in Ontario; used as calcium lime for metallurgical flux and for the manufacture of chemicals; rock of lower purity is used for cement manufacture, agricultural lime and aggregate; Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: quarried near Port Dover and on Pelee Island for crushed stone; used at St. Marys as a raw material for Portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse-grained, grey-brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2-14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses.

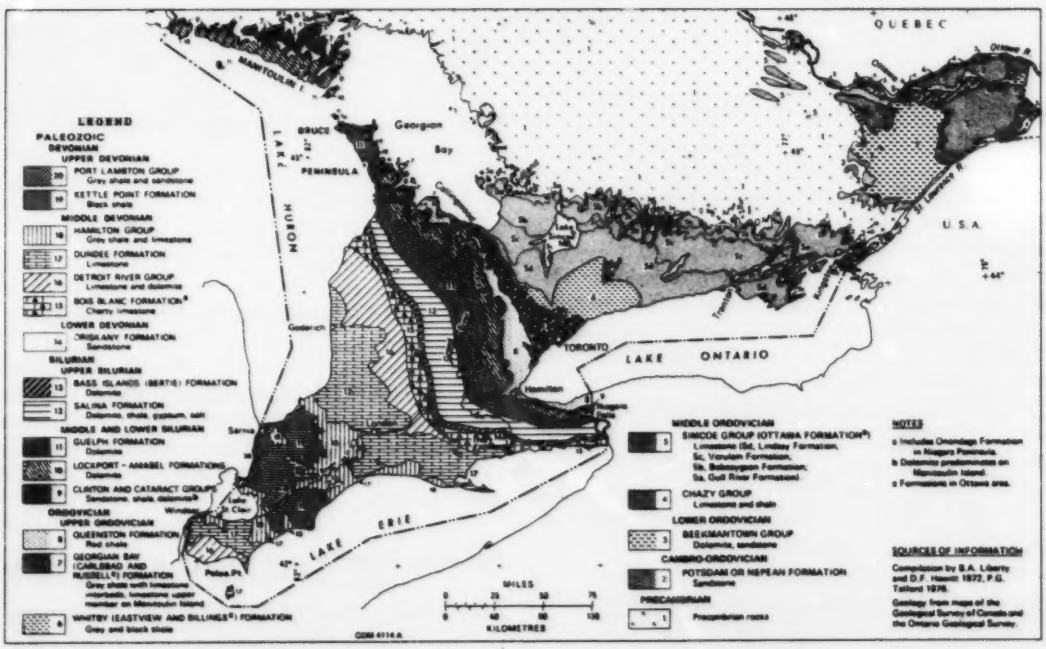


Figure D1. Bedrock geology of Southern Ontario.

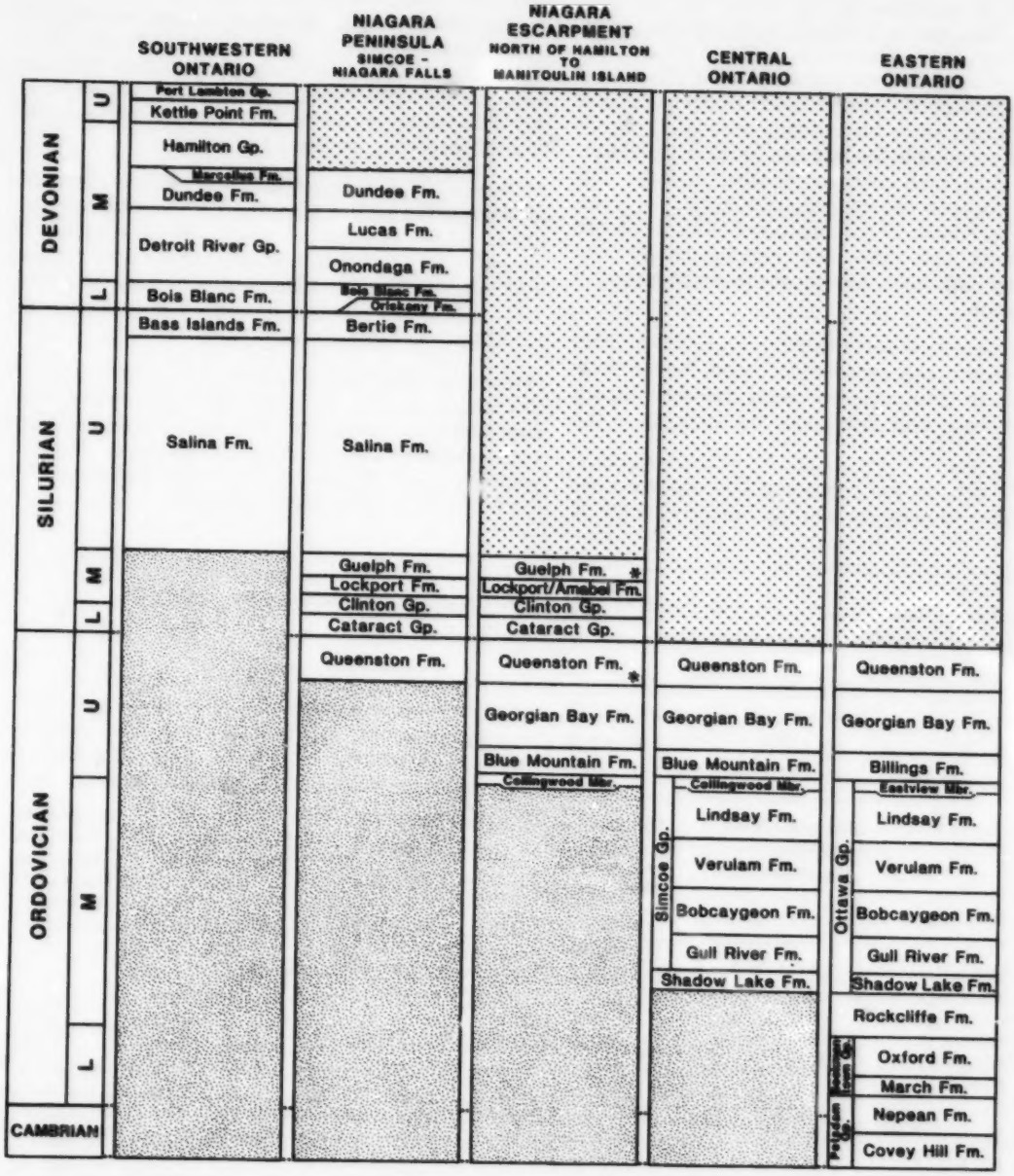


Figure D2. Exposed Paleozoic Stratigraphic Sequences in Southern Ontario
(adapted from: Bezys, R. K., and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Canadian Mining and Metallurgical Bulletin v.81, no.912, p.49–58).

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of Table E1 and the specification limits for each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Los Angeles abrasion and impact test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE E1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness – Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	–	–	60	–
16 mm Crushed Type 'A'	160	–	–	35	–
16 mm Crushed Type 'B'	200	–	–	60	–
Granular Subbase B	250	–	–	–	–
Granular Subbase C	250	–	–	–	–
Granular Subbase D	–	–	–	–	–
Hot Mix – HL 1	100	5	1.0	15	16
Hot Mix – HL 2	–	–	–	–	20
Hot Mix – HL 3	135	12	1.75	35	16
Hot Mix – HL 4	160	12	2.0	35	20
Hot Mix – HL 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

MAPS
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CARTES
OMISES